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(71) Applicant
British Gas plc
(Incorporated in the United Kingdom)
152 Grosvenor Road, London SW1V 3JL, United Kingdom

(72) Inventor
Paul Beaumont Cordes

(74) Agent and/or Address for Service
Robert J Cummings
British Gas plc, 326 High Holborn, London, WC1V 7PT, United Kingdom

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US 4008469 A
Horowitz & Hill: The Art of Electronics C.U.P. S9.37

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(54) **Method and apparatus for radio transmission using pulses of random polarity**

(57) The maximum power in any spectral line of a spectrum which would represent radio emission (for example in ground probing radar) is reduced by splitting each line into a number of lines each of lower power. The original train of pulses 10 is used to generate both positive-going and negative-going pulses 32, 34 using the logic output of a PRBS (pseudo-random binary sequence) generator 16 to steer pulses to either of two pulse generators 18, 20. Their outputs are combined by a power combiner 26. A sampling receiver system (Fig. 6) is phase controlled by the output of the PRBS generator. Typically a spectrum which would have resulted from transmission of pulses 1ns wide at 12ns spacing has the maximum energy per line reduced from 1300nW by a factor of 2^{16} by splitting each line into 2^{16} further lines where 2^{16} is the length of the PRBS code.

FIG. 5.

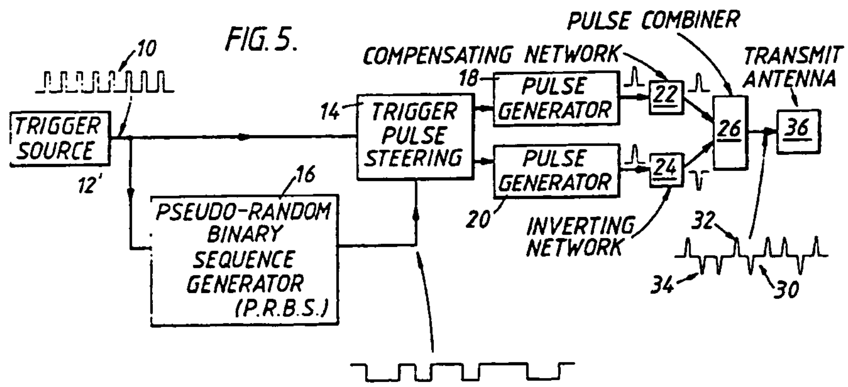

FIG. 6.

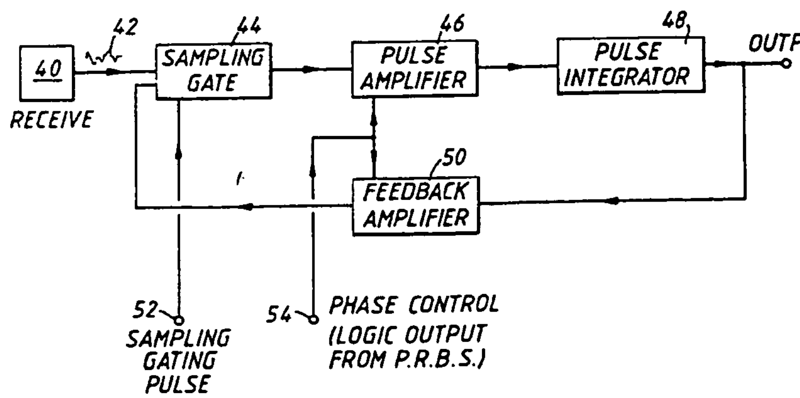

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FIG. 1.

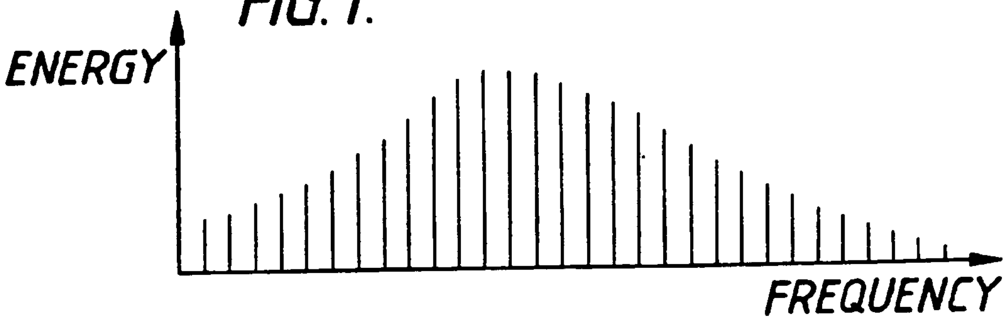


FIG. 2.

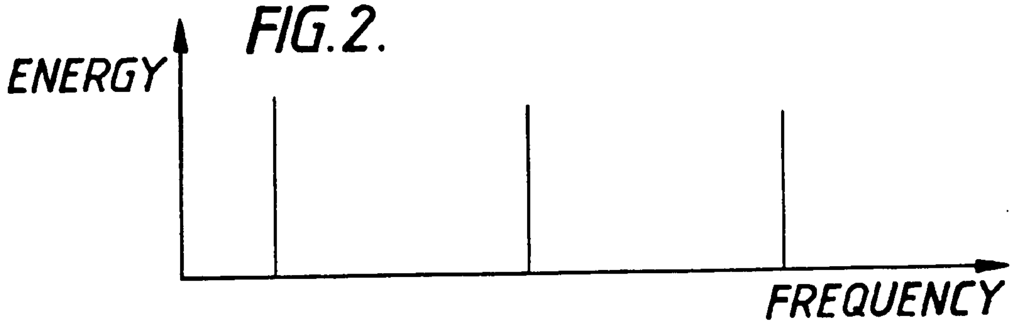


FIG. 3.

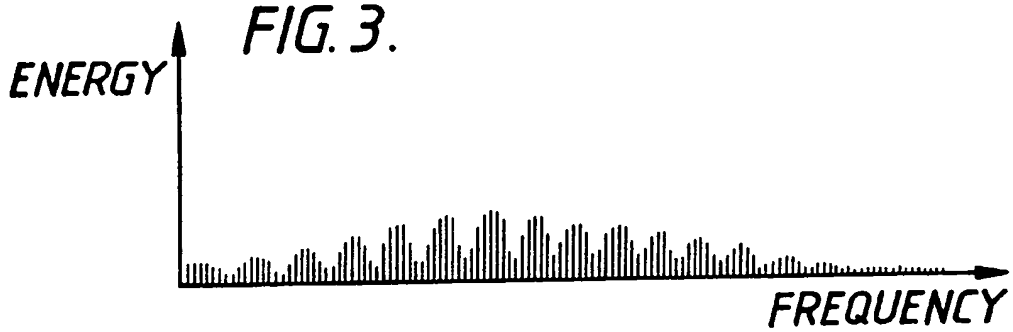


FIG. 4.

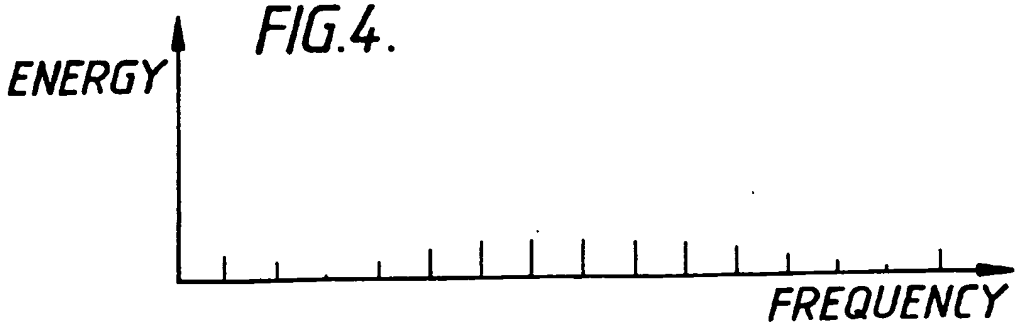


FIG. 5.

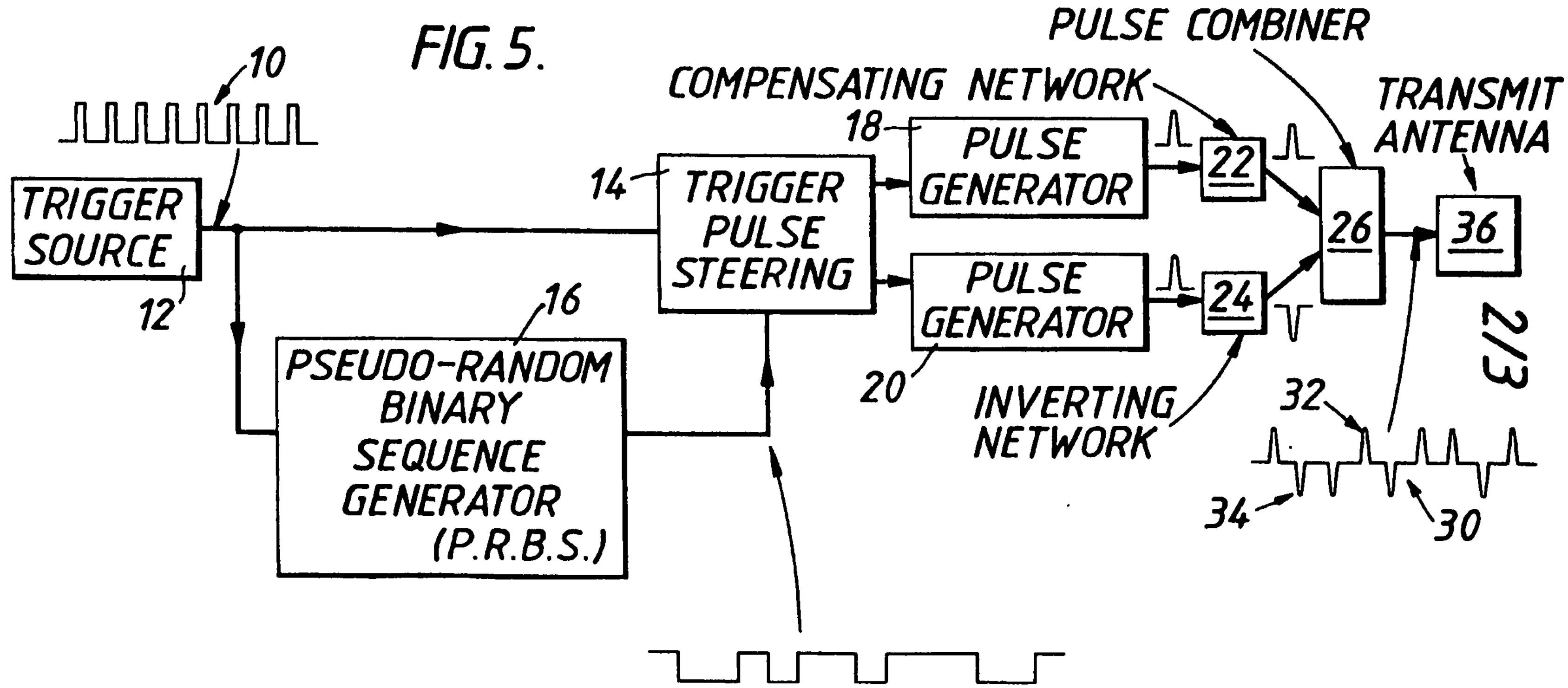
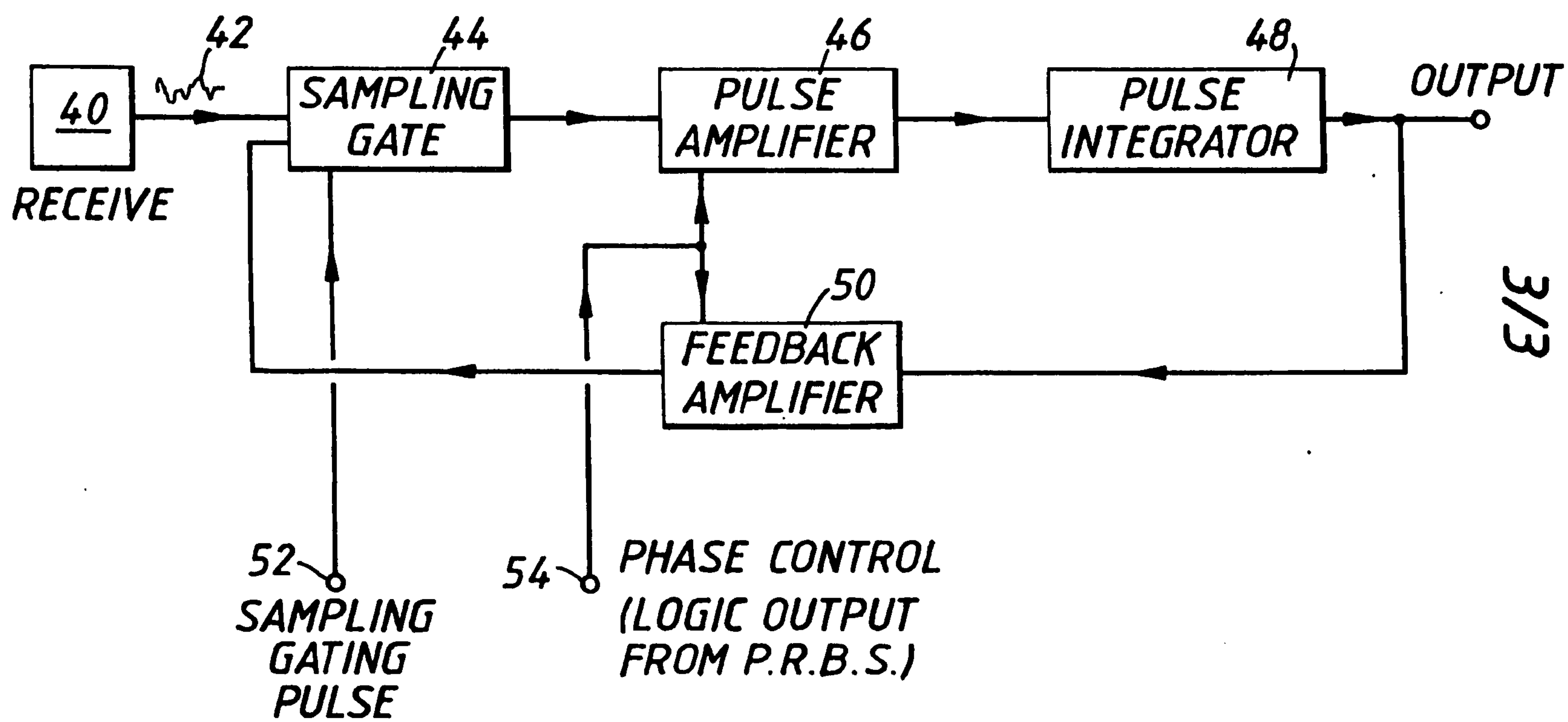

10
TRIGGER SOURCE
12
14
TRIGGER PULSE STEERING
16
PSEUDO-RANDOM BINARY SEQUENCE GENERATOR (P.R.B.S.)
COMPENSATING NETWORK
18
PULSE GENERATOR
PULSE GENERATOR
20
22
24
INVERTING NETWORK
PULSE COMBINER
26
TRANSMIT ANTENNA
36
32
34
30

FIG. 6.


40
RECEIVE
42
44
SAMPLING GATE
46
PULSE AMPLIFIER
48
PULSE INTEGRATOR
OUTPUT
50
FEEDBACK AMPLIFIER
52
SAMPLING GATING PULSE
54
PHASE CONTROL (LOGIC OUTPUT FROM P.R.B.S.)

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METHOD & APPARATUS FOR RADIO TRANSMISSION

The invention relates to methods and apparatus for radio transmission, particularly though not exclusively for use as part of ground probing radar in locating objects buried in the ground.

Safety considerations require spurious emissions of power from transmitters of radio frequencies to be limited. For example in the United Kingdom the Department of Trade and Industry has issued regulations requiring such emissions to be below 4 nanowatts (nW) at any frequency in certain bands used for Instrument Landing System (ILS) applications and below 250nW wlsewhere in the range 0 to 2000 MHz. Such considerations apply to radar transmitters, for example, and the invention provides a method and apparatus applicable particularly, though not exclusively, to ground-probing radar transmitters used for locating pipes and cables buried underground.

In a typical ground-probing radar system, for example, the transmitter emits pulses of electromagnetic energy at intervals of 12ns, the pulse width being 1ns. The energy radiated is distributed among frequencies spaced apart by 82.5 kHz and ranging in a spectrum from zero to over 1 GHz. Each such frequency may be considered to be in a line in the spectrum, the height of each line representing the energy associated with that particular frequency (see

Figure 1). The maximum power in watts in a line is approximately $(ftV)^2/50$ when the transmitter is terminated by a load of 50 ohms, where f is the pulse repetition frequency, t is the pulse width in seconds and V is the amplitude of the pulses in volts.

Typically, for example, f = 80 kHz, t = 1ns and V = 100 volts. In that case the maximum spectral line power is 1300nW, which exceeds the desired maximum of 4nW by a factor of 325. The maximum spectral line power could be reduced by, for example, reducing the pulse amplitude by a factor of $(325)^{1/2}$ to 5.6 volts or by reducing f to 4.5 kHz. Neither of those solutions is acceptable.

The object of the invention is to provide a method and apparatus by which the maximum spectral line power can be reduced by distribution of the transmitted power among a relatively larger number of spectral lines.

According to the invention, a method of effecting radio transmission comprises generating a first train of pulses all of the same polarity and deriving from said first train a second train of pulses containing pulses of said first polarity and pulses of second polarity opposite to the first and feeding said second train of pulses to a transmitter antenna to produce an emission therefrom whereby in the spectrum of said emission energy transmitted from the antenna is distributed among a

greater number of spectral frequencies and the maximum energy in any spectral frequency is less than it would have been had said second train of pulses all been of the same polarity.

Preferably said second train of pulses is formed by combining a first sequence of pulses of said first polarity with a second sequence of pulses of said second polarity, ssaid first and second sequences is derived from the outputs of respective first and second pulse generators, pulses of said first train being routed as input to one or the other of said first and second pulse generators according to the logic output condition of a pseudo-random binary sequence (PRBS) generator.

According to the invention radio transmitter apparatus comprises a source producing a first train of pulses all of the same polarity, first and second pulse generators, a compensating network and in inverting network receiving the outputs from said first and second pulse generators respectively and producing respectively a first sequence of pulses all of a first polarity and a second sequence of pulses all of a second polarity opposite to said first polarity, a power combiner receiving said first and second sequences and producing a second train of pulses containing pulses of said first polarity and pulses of said second polarity, a transmitter antenna to which said

second train of pulses is fed, a pseudo-random binary sequence (PRBS) generator to which said first train of pulses is fed, and pulse steering means controlled by said PRBS to which means said first pulse train is fed and which means feeds pulses thereof to said first pulse generator or to said second pulse generator according to the condition of a logic output from said PRBS generator whereby in the spectrum of emission from said antenna energy transmitted thereby is distributed among a greater number of spectral frequencies and the maximum energy in any spectral frequency is less than it would have been had said second train of pulses all been of the same polarity.

An embodiment of the invention will now be described with reference to the accompanying drawings in which :-

Figures 1 & 2 show, respectively, a spectrum of energy plotted as ordinate and frequency plotted as abscissa for a known typical emission from a ground-probing radar antenna; and a detail of the spectrum shown in Figure 1 but with the abscissa scale enlarged;

Figures 3 & 4 show, respectively, the spectrum which results from the use of the invention to reduce the maximum energy contained in any spectral line of an emission which would otherwise have a spectrum as shown in Figure 1; and a detail of the spectrum shown in Figure 3 but with the abscissa scale enlarged to the same scale as

in Figure 2; and

Figures 5 & 6 are block diagrams of radio transmitter apparatus and radio receiver apparatus for use in performing the method according to the invention.

In what follows it is assumed that the method of radio transmission is used as a ground probing radar method for the purpose of locating buried objects such as pipes and cables, for example. However the invention is applicable to radio transmission used for other purposes, whether as radar or otherwise.

In this example, for ground probing radar, a known method is to generate, for example, a train of pulses separated by 12 nanoseconds, and to use the train of pulses to generate a further train of pulses, all of the same polarity and each pulse being 1ns wide, which are fed to a transmitter antenna.

Figures 1 and 2 illustrate the effect of energising the transmitter antenna by feeding such a train of pulses directly to the antenna. Figure 1 shows the energy spectrum of the resulting emission from the antenna. Owing to the repetition of the pulses and the narrow width of each pulse, the spectrum comprises spectral lines spaced apart by the reciprocal of the interval "T"

separating the pulses. In this example T = 12ns. The spacing is accordingly 82.5 kHz and the spectrum extends from zero to well over 1 GHz.

As already mentioned above the maximum energy in a spectral line is $(ftV)^2/50$ when a 50-ohms load is used to terminate the antenna. In this example as already stated above the maximum power is some 1300nW, which is some 325 times too high to be acceptable.

Figure 2 shows the spectral lines on an expanded frequency scale.

Figures 3 and 4 show the effect of using the invention. The spectrum of the emission from the antenna, as shown in Figure 3, contains many more spectral lines compared with the spectrum shown in Figure 1 and the maximum energy in any spectral line is considerably reduced. For example, the maximum energy is reduced from 1300nW by a factor of 2^{16}. Each line in the original spectrum has been effectively split into a number of lines and the further description below explains how the number of new spectral lines depends on the length of a pseudo-random binary sequence (PRBS) code which is used to generate from the original train of pulses the further train which is used to energise the transmitter antenna.

Figure 3 shows that there is a relatively small periodic

variation in the amplitude (energy) of the spectral lines. The total transmitted energy is the same but the use of the invention enables the limits set by the regulations mentioned above, for example, to be readily met.

Figure 5 shows one example of how the invention can be performed. The original train of pulses is indicated at 10 as the output of a trigger source 12. Each pulse is, for example, a rectangular pulse of finite width. The output 10 from the source 12 is fed to a trigger pulse steering circuit means 14 and also in parallel to a PRBS generator 16.

The means 14 directs the pulses to one or other of two pulse generators 18, 20 according to whether the logic output condition of the PRBS generator 16 is high or low. The generators 18, 20 each produce pulses of suitable shape and of finite width e.g. 1ns. The outputs from the generators 18, 20 are fed, respectively, to a compensating network 22 and to an inverting network 24. The inverting network produces negative-going pulses. The compensating network 22 compensates for the distortion in the inverting network 24, which is of relatively restricted band width, so that the two pulse outputs are of the same shape and remain in the correct time relationship. The two outputs are combined in a pulse combiner circuit 26. The resulting output is a final train of pulses 30 which

contains both positive-going pulses 32 and negative-going pulses 34.

If necessary some method may be employed to match the output pulse shapes of the two generators so that optimum combining takes place. In a modification, the generators 18, 20 and networks 22, 24, respectively, can be combined, one combination giving a positive pulse and one a negative pulse.

The final pulses are fed to an antenna 36 which is energised by the pulses and emits corresponding electromagnetic radiation into the ground. The emitted radiation is back-scattered by objects buried in the ground such as pipes and cables, for example. A receive antenna 40 (Figure 6) responds to back-scattered radiation and produces a continuous analogue voltage output 42.

The output 42 is fed to a sampling gate circuit 44 which produces pulses which are amplified by an amplifier 46 and integrated by an integrator circuit 48.

The integrated output from the integrator 48 is fed back via a feedback amplifier 50 to an input of the sampling gate 44, which responds to the error between the input from the receive antenna and the feedback signal. The sampling gate 44 receives a pulse input at 52, which times the sampling gate 44 in the correct relationship with the

signal transmitted by the transmit antenna 36. The output from the PRBS generator (Figure 5) is fed to both the amplifier 46 and the feedback amplifier 50 from an input 54. The phase of the amplifier 46 and the feedback amplifier 50 are thus both switched to match the output from the transmit antenna 36.

The outlines given above of the transmit and receive circuit arrangements are by way of example only and other configurations are feasible within the scope of the invention.

If the pseudo-random code determined by the PRBS generator has a length of n conditions (i.e. high or low) then each line of the original spectrum shown in Figure 1 is effectively split into n lines to give the spectrum shown in Figure 3.

The PRBS is predictable and repeats itself. It is not essential to use a pseudo-random code. Any suitable code may be used to produce a final pulse output which contains both negative-going and positive-going pulses.

Typically, for example, in the case of the ground-probing radar transmission system described above with reference to the drawings the PRBS code has 2^{16}-1 conditions, after which the code repeats. Accordingly, the number of

spectral lines is increased by a factor of 2^{16}. The maximum power in any line is reduced from 1300nW by a factor of 2^{16} i.e. to virtually zero.

Successive pulses in the train 30 are spaced apart by 12ns and are 1ns wide, for example. The train of pulses 30 is fed to a transmit antenna 36, which emits electromagnetic radiation, either at a reference object or into the ground. The presence effectively of equal numbers of both positive-going and negative-going pulses in random distribution in the train 30 results in an energy spectrum of the kind shown in Figures 3 and 4. There are many more spectral lines generated than are contained in a spectrum of the kind shown in Figures 1 and 2.

It will be understood that radio transmission as used herein also means transmission from a spurious transmitter, such as a power supply unit for example. Thus, the present invention is advantageously applicable to such spurious transmitters to limit the emission of power even where the receiver is unconnected with the transmitter.

CLAIMS

1. A method of effecting radio transmission comprises generating a first train of pulses all of the same polarity and deriving from said first train a second train of pulses containing pulses of said first polarity and pulses of a second polarity opposite to the first and feeding said second train of pulses to a transmitter antenna to produce an emission therefrom whereby in the spectrum of said emission energy transmitted from the antenna is distributed among a greater number of spectral frequencies and the maximum energy in any spectral frequency is less than it would have been had said second train of pulses all been of the same polarity.

2. A method according to claim 1 said second train of pulses is formed by combining a first sequence of pulses of said first polarity with a second sequence of pulses of said second polarity, said first and second sequences is derived from the outputs of respective first and second pulse generators, pulses of said first train being routed as input to one or the other of said first and second pulse generators according to the logic output condition of a pseudo-random binary sequence PRBS generator.

3. A method according to claim 1 or claim 2 said transmission being received by a sampling receive system.

4. A method according to claim 2 said transmission

being received by a sampling receive system in which phase is controlled by the output from said PRBS generator.

5. Radio transmitter apparatus comprising a source producing a first train of pulses all of the same polarity, first and second pulse generators, a compensating network and an inverting network receiving the outputs from said first and second pulse generators respectively and producing respectively a first sequence of pulses all of a first polarity and a second sequence of pulses all of a second polarity opposite to said first polarity, a power combiner receiving said first and second sequences and producing a second train of pulses containing pulses of said first polarity and pulses of said second polarity, a transmitter antenna to which said second train of pulses is fed, a pseudo-random binary sequence (PRBS) generator to which said first train of pulses is fed, and pulse steering means controlled by said PRBS to which means said first pulse train is fed and which means feeds pulses thereof to said first pulse generator or to said second pulse generator according to the condition of a logic outut from said PRBS generator whereby in the spectrum of emission from said antenna energy transmitted thereby is distributed among a greater number of spectral frequencies and the maximum energy in any spectral frequency is less than it would have been had said second train of pulses all been of the same polarity.

6. Apparatus according to claim 5 associated with receiver apparatus comprising a receive antenna, a sampling gate receiving the output from said antenna, a pulse amplifier amplifying the output of said gate and a pulse integrator integrating the output from said amplifier, a feedback amplifier receiving the output from said integrator and providing an input to said gate, said pulse amplifier and said feedback amplifier both receiving the output from said PRBS genertor as phase control.

7. A method according to claim 1 substantially as herein described with reference to Figures 1 to 4 of the accompanying drawings.

8. A method according to claim 1 substantially as herein described with reference to Figures 1 to 5 of the accompanying drawings.

9. A method according to claim 3 substantially as herein described with reference to Figures 1 to 6 of the accompanying drawings.

10. Apparatus according to claim 5 substantially as herein described with reference to Figure 5 of the accompanying drawings.

11. Apparatus according to claim 6 substantially as

herein described with reference to Figures 5 & 6 of the accompanying drawings.

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